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ABSTRACT

An audio-tutorial learning system for college students studying intermediate algebra was developed by a member of the mathematics staff and was directed by student assistants. An analysis of covariance design was used to determine if students receiving help from student assistants did significantly better than those not receiving help. Results showed that when initial abilities in mathematics (as determined by Blyth Algebra pretest and College Entrance Examination Board scores) were held constant, the group receiving no help had a significantly higher Blyth Algebra posttest mean score. Both groups achieved significantly above the national average. (Author/DT)

Final Report

Project No. 2F004
Contract No. OEC-6-72-0725-(509)

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THE DEVELOPMENT OF AN INDIVIDUALIZED LEARNING SYSTEM FOR STUDENTS STUDYING INTERMEDIATE ALGEBRA

July 6, 1973

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

ABSTRACT

An audio-tutorial learning system for college students studying intermediate algebra was developed and directed by student assistants. A member of the mathematics staff developed the system and assigned final grades. Otherwise, the mathematics staff was not involved.

An analysis of covariance design was used to determine if students receiving help from student assistants do significantly better than those not receiving help. Initial abilities in mathematics as determined by Blyth Algebra pretest, discriminatory analysis, and College Entrance Examination Board scores were held constant. The group receiving no help had a significantly higher Blyth Algebra post test mean score when the Blyth Algebra pretest and College Entrance Examination Board scores were held constant. Both groups achieved significantly above the national average.

It was concluded that college students capable of directing their own learning can successfully master intermediate algebra concepts when the students are placed in a well defined self pacing audio-tutorial learning system. Students faced with no teacher help available may work more intensely and achieve at a significantly higher level than students receiving help on a systematic basis. Instructional cost for precalculus mathematics instruction may be reduced by as much as forty percent over a five year period.

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The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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PREFACE

This research report is the culmination of a project which began in the summer of 1971. Much credit for the research proposal as originally conceived goes to Dr. Willis Alderson, former assistant to the President, Hendrix College. His encouragement was a source of strength as the project went through various forms of revision. It would be remiss if special appreciation were not given to Dr. Burvin C. Alread, the contracting officer for Hendrix College and Mr. Rodney Todd, chief accountant and business manager for their advice in connection with record keeping, interim reports, and expenditures. Finally, no value can be placed on the contribution that Pat Huggler, Debra Roberts, Cathy McLendon, and John Lovett made to this research project. Each was dependable, competent, and dedicated. Each assisted the project director by carrying out instructions affecting the research in such a way that no crisis was experienced during the eighteen month duration of the project. Their selection as assistants proved to be extremely wise.

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I. INTRODUCTION

Purpose of the Study

The purpose of this study was to develop a program of individualized instruction for students not adequately prepared for elementary functions, the first course in mathematics at Hendrix College. Students not prepared for elementary functions as determined by a discriminatory analysis guide were placed in an intermediate algebra learning sequence. The sequence utilized an audio-tutorial learning system based on an audio-tutorial text, keyed in tapes and filmstrips, and problem sessions. The student's progress was measured by using a standardized pretest, unit tests, and standardized post test. The student's attitudes were measured by an attitude survey.

Local Implications of the Study

The Hendrix College mathematics department developed a discriminatory analysis guide in 1971 for the purpose of placing students in either calculus, elementary functions, or contemporary mathematics. A copy of this guide is in Appendix A. The traditional two term sequence in algebra and trigonometry was removed in the spring of 1971 and replaced by a more rigorous one term course in elementary functions. It was anticipated at the time of this proposal that 130 to 150 students would take elementary functions each of the school years 1971-72 and 1972-73. Because of the lack of high school preparation it was anticipated that 20 to 30 of these students would need to participate in an intermediate algebra course during each of the school years 1971-72 and 1972-73. It should be noted that 116 students took elementary functions during the school year 1971-72 and 147 during 1972-73 and 78 participated in an experimental intermediate algebra course during 1971-72 and 1972-73. The situation was predicted and turned out to be one that provided an opportunity to conduct some research related to the development of an efficient learning system that would solve a problem and make it possible for a mathematics staff to reallocate its time without affecting the precalculus mathematics instructional program.

General Overview of the Learning System and Cost Factors

The learning system developed and used in the experiment associated with this project was designed specifically for college mathematics instruction using the particular combination of instructional

devices: a discriminate analysis placement process, an audio-tutorial text, keyed in Cassette tapes and filmstrips, a standardized pretest, unit test, a standardized post test, a student coordinated testing program, and problem sessions. The system was developed by this researcher with assistance from a mathematics education student, Debra Roberts, and then operated by two mathematics majors, Pat Huggler and John Lovett. Although some components of the system were developed to meet the specific needs of Hendrix College freshmen mathematics students, the organizational structure was developed in such a way that it can be readily adapted to other colleges. As will be made clear in this report, the learning system can be used to reallocate staff resources, yet efficiently teach elementary precalculus mathematics concepts. The total cost for 76 students taking intermediate algebra by traditional instruction would have been \$3750.00 or \$53.00 per student. This figure is based on the salaries of the two instructors who would have devoted 12.5% of their time to the courses.

If the system had not been in an experimental mode, that is no experiment had been conducted, the cost would have been \$3040.00 or \$40.00 per student. This figure includes \$780.00 for student help, \$1760.00 for equipment and materials, and \$500.00 for supervision, student placement, and student evaluation by the mathematics staff. It is easy to see that the second year the system operates the cost of equipment is reduced and therefore total cost is reduced. It is this researcher's opinion that the system would only cost \$32.00 per student over a five year period whereas regular instruction would be about \$60.00 considering increased salaries. Although these figures are based on the situation at Hendrix College, do not include indirect costs which are the same for either method of instruction, and relate to 76 students, the comparisons in cost of teaching methods with similar results is dependable and significant.

The Learning System--Operational Details

A freshman at Hendrix College is placed in either calculus, elementary functions, or contemporary mathematics (a general education non-skills course). Students placed in contemporary mathematics but desiring to take elementary functions at some future time are encouraged to enroll in "Math Lab." Math Lab utilizes the learning system developed in this project. It is a credit no-grade course and is strictly preparation for elementary functions. It does not meet any mathematics requirement but is counted as an elective toward the 36 courses required for graduation.

Students assigned to Math Lab assemble together the evening of the first day of classes for the term. A mathematics instructor describes the learning system in which each student participates. During the course of the experiment outlined in the next section of this report, this researcher described the system and randomly assigned students to the experimental and control sections. Students' schedules are studied and ten class periods set up each week as help or

testing sessions. This is done in such a way that each student can receive help or take a test at least three times each week. During the experiment students receiving no help were not allowed to attend problem sessions.

During the Math Lab opening class session the audio-tutorial text is discussed in detail and the manner in which the Cassette tapes and filmstrips are to be used is described. Equipment such as tape players, earphones, and filmstrip viewers are demonstrated and then located in a room in the main college library. Four work stations are made available for use by Math Lab students. Record forms are given to each student and each is encouraged to record the time actually devoted to the course including problem sessions and test sessions. During the course of the experiment the record forms were occasionally checked so as to encourage record keeping. Clocks are provided in the Math Lab testing room and in the library study room for convenience.

With these instructions the Math Lab becomes operational. Consider student A. The first convenient period (one of the ten periods set up in the opening class session) student A comes to the Math Lab testing room and takes the standardized pretest given by student assistants. A file for student A is established and his pretest score recorded. Student A then starts the course. After studying unit one and working various types of study exercises, viewing the films provided, and listening to tape lectures related to the material, the student comes in at an appropriate time and takes unit test one. He is careful to record the time devoted to unit one. Unit one test is administered by a student assistant and the score recorded. If the student make 70% or better he is allowed to go on to the next unit. If the student makes less than 70% he must take an alternate form of the unit test when he is better prepared. This process is continued until all 14 units are completed. After the last unit test has been successfully completed the student takes a standardized post test, turns in his time sheet, completes an attitude survey intended as a monitor on the operation of the program, and therefore completes the course. At the end of the term the student assistants turn in the files on all students to the chairman of the mathematics department. A grade of P is given to all students who complete twelve units with a minimum of 70% on each unit or a post test score of 26.* If a student does not complete either of these criteria and does not plan to do work during the next term, the student can drop the course with appropriate notification in accord with college regulations. If the student does not complete 14 units and plans to complete the course during the next term, the student is given a grade of I and one additional term to complete the course. During the experiment, all students were given exactly one term to complete the course.

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*The June 9, 1972 Progress report indicated that a student must have a minimum score of 60% on 12 units or a post test score of 21. This standard was updated after a careful analysis of the data obtained from the trial run during the spring of 1972.

Related Literature

Experiments using linear programs, branch programs, computerized instructions, video tapes, and oral programming have been conducted throughout the United States with some significant results. Industry and the armed services have developed learning packages that are extremely effective in the sense that facts are retained and applied successfully over 30-90 day periods without reinforcement. The Sigma Project, the Hendrix Experiment, and the PLAN oral programming experiment are examples of programs in individualized instruction in which this researcher has utilized educational technology in forming new educational patterns. These programs relate to teachers, elementary or secondary school children, or elementary forms of learning--but not specifically to college mathematics students. These programs utilize only one or two methods of presenting concepts. In fact, this is characteristic of most experiments currently being conducted which relate to individualized instruction.

The experiment described in this project involves two complete learning systems, components of which give a new linear ordering but each component or learning experience was selected in accord with recent research findings. The educational technology used was selected so as to maximize the learning of a given unit.

The audio-tutorial materials developed under Project 70 at Fullerton, California were utilized. Copies of the audio-tutorial text, Intermediate Algebra, by Gus Klentos and Joseph Newmyer which came out of Project 70 were purchased from Charles E. Merrill Publishing Company. Tradition filmstrips were keyed into three of the 14 units selected for the experiment using a Bell and Howell Cue recorder and Singer synchronized Cassette filmstrip viewers. Audiotronic players and headsets were used in four student carrels.

II. EXPERIMENTAL METHODS

Description of the Comparable Learning Systems

Two audio-tutorial learning systems were developed and compared. The following is a linear ordering of the components of each of the systems.

Learning system α consists of 7 components.

1. Each student was placed in Math Lab based on a discriminatory analysis guide and student need for preparation for elementary functions. Placement in experimental group α was done using random numbers.

2. A one hour introduction to the learning system was given by a mathematics instructor for the entire group. When enrollment was completed, record forms were established for each student.

3. By utilizing student schedules, ten hours each week were set up as test sessions so that each student had at least three hours available for testing. This ten hour schedule is referred to as the Math Lab schedule.

4. A Blyth Algebra pretest was completed at the student's convenience within the limits of the Math Lab schedule.

5. The student worked through 14 units of intermediate algebra using audio-tutorial text, filmstrips, and Cassette tapes. A unit was completed after a unit test score of 70% was obtained. Two forms of each unit test were available. All unit tests were administered by student assistants during the scheduled ten hour test sessions. The student recorded the time devoted to each unit of study.

6. The Blyth Algebra post test was taken after unit 14 was completed or at the end of the term.

7. An attitude survey was completed by the student and the record of time devoted to the course was placed in the student's record file.

Learning system β consists of the components of learning system α and an additional component. Briefly the components for β are:

1. Student placement.

2. One hour introduction and establishment of record forms.

3. Development of Math Lab schedule.

4. Blyth Algebra pretest.

5. Work through 14 unit[illegible] hlished procedure.

6. A student may receiv[illegible] [illegible]p from the student assistants at the student's convenience within the limits of the Math Lab schedule. This is the additional component.

7. Blyth Algebra post test.

8. Attitude survey and record of time form.

The students assigned to learning system α will be referred to as experimental group α. The students assigned to learning system β will be referred to as control group β. Group α received no help. Group β received help. Tables 1 and 2 indicate the learning experiences by unit for groups α and β. Appendix B provides a list of the topics treated in the 14 units.

Audio-Tutorial Methods

In the study of mathematics, most students are accustomed to the traditional lecture-textbook method where they read a certain section in the text, go to class to hear a lecture on the material, then are left to try to work the exercises. The frustrations of this type of situation are many. First, most students have difficulty reading a mathematics textbook; second, once the classroom lecture is over, the chalkboard is erased and the explanatory lecture is lost; and third, many students have great difficulty working the homework assignment a few hours after the lecture.

The audio-tutorial materials used in this experiment are an attempt to remedy the defects of the traditional lecture-textbook method. In the audio-tutorial approach, the lecture and other explanations are put on audio tape. The chalkboard illustrations are put in the text. Therefore, each student has a permanent record of the material generally presented in the classroom. The student may go through the lecture at his own rate, and any part of the lecture may be reviewed as often as desired by simply reversing the recorder and turning back a few pages in the text.

Experimental Design and Methods of Procedure

Two audio-tutorial learning systems were compared. The time scheduled for each system was 68 days including 18 week-end days.

TABLE 1

LEARNING EXPERIENCES BY UNIT
EXPERIMENTAL GROUP α

Learning Experience	Unit 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Description of Math Lab	x													
Blyth Algebra pretest	x													
View filmstrip with sound			x				x			x	x			
Read audio-tutorial text	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Listen to tape	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Attend problem sessions														
Take unit test	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pick up test results	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Blyth Algebra post test														x
Attitude survey														x

TABLE 2

LEARNING EXPERIENCES BY UNIT
CONTROL GROUP β

Learning Experience	Unit 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Description of Math Lab	x													
Blyth Algebra Pretest	x													
View filmstrip with sound			x				x			x	x			
Read audio-tutorial text	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Listen to tape	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Attend problem session	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Take unit test	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pick up test results	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Blyth Algebra post test														x
Attitude survey														x

System α was characterized by the fact that students could not receive any help from the student assistants operating the Math Lab or from any member of the Hendrix College Mathematics faculty. System β was characterized by the fact that students could receive help from the student assistants operating the Math Lab but could not receive help from members of the Hendrix College Mathematics faculty.

A trial run of the two learning systems defined in a previous section of this report was carried out in the spring of 1972. The instructional materials were developed and debugged. Adequate record forms, standardized tests, audio-tutorial text, and audio-tutorial instructional aids were operational by June 15, 1972. Fourteen instructional units were selected and two sets of unit evaluations prepared. An experimental group of 16 students participated in a trial run of the learning system during the March 15-June 1 spring term. As a result of this trial run, a research design was selected and the two audio-tutorial learning systems α and β were made operational during the first and second terms of the 1972-73 school year. A significant objective of this project was achieved when it became clear that by June 15, 1972 an audio-tutorial learning system for intermediate algebra had been developed. This had been done in such a way that selection procedures, instructional materials, machines, and directors of learning activities functioned as a manageable unit; that is, the system could be controlled, monitored, and placed in an experimental data gathering mode.

The analysis of covariance design was selected and used to evaluate learning systems α and β. Since not all data to be used in the control variables could be gathered, three different analysis of covariance F ratios were computed. The variables held constant in each of the procedures were Blyth Algebra pretest, discriminate analysis V score, and College Entrance Examination Board Mathematics score. An attitude survey was developed to compare the students' attitudes toward various components of each learning system. The Olivetti Underwood P101 computer was used to analyze all data with programs developed by the project director and Cathy McLendon, a senior mathematics major.

III. RESULTS

An analysis of covariance design was used to test the difference between post test means of experimental group α and control group β. Since three different variables were held constant, three analysis of covariance treatments were carried out. Tables 3 and 4 give the data used in the three treatments. Tables 5, 6, and 7 show the analysis of covariance summary tables. When pretest scores were held constant there was a significant difference at the .01 level between the post test means of group α and group β with group α having the higher mean score. When discriminate analysis V scores were held constant there was no significant difference at the .01 level between the post test means of group α and group β. When the College Entrance Examination Board Mathematics scores were held constant there was a significant difference at the .01 level between the post test means of group α and group β with group α having the higher mean score.

An F statistic was computed to test the null hypothesis $H_o: \sigma_\alpha = \sigma_\beta$ against the alternate hypothesis $H_1: \sigma_\alpha \neq \sigma_\beta$. Table 8 gives the results associated with this statistical test. H_o was accepted at the 0.01 level.

Several other statistical studies were carried out although some were not mentioned in the project proposal. Appendix C charts the number of hours devoted to the course by each student in both group α and β. Table 9 provides a statistical analysis of the time devoted to the course. There was no significant difference between the mean scores for the two groups. It should be noted that 15 of the 31 students in group α devoted over 30 hours to the course while only 9 of the 27 students in group β devoted over 30 hours to the course. Appendix D gives the final grades assigned to each student in both group α and β. A grade of P was pass and a grade of F was fail. Only one student in group α failed the course. Four students in group β failed the course. It should be noted that the failure rate of approximately ten percent is slightly less than the thirteen percent failure rate experienced from 1967-71 in college algebra courses at Hendrix College.

The unit test played a role in motivation in the course in that a student could not go on to the next unit of study without making a score of at least 70% on a unit test. Each test had 20 questions and two forms of each unit test were available. A particular unit test for a particular student was selected in a random manner. If a student had to take a unit test a second time, then the alternate test was given. Appendix E indicates there was a Pearson r correlation of 0.611 between unit test average scores and post test scores for group α and a

TABLE 3

GENERAL DATA
EXPERIMENTAL GROUP α

Student Code	Blyth Algebra Pretest	CEEB Math	V Score	Blyth Algebra Post test
1	20	580	1.03	33
2	23	590	0.85	25
3	16	480	0.60	22
4	16	x	x	24
5	24	600	x	40
6	12	450	x	35
7	6	470	x	34
8	17	x	x	29
9	21	450	0.32	25
10	12	450	0.46	30
11	18	390	0.27	32
12	23	x	x	37
13	18	540	-0.08	24
14	20	370	0.33	35
15	30	x	x	41
16	15	x	x	30
17	15	310	0.24	38
18	25	450	0.10	39
19	29	420	0.63	36
20	11	380	-0.15	22
21	21	530	0.65	36
22	33	500	0.92	45
23	13	x	x	30
24	19	500	x	28
25	19	470	0.70	36
26	33	670	x	40
27	14	480	x	24
28	21	490	0.34	33
29	18	450	0.11	31
30	23	510	x	40
31	16	430	-0.43	25

TABLE 4

GENERAL DATA
CONTROL GROUP β

Student Code	Blyth Algebra Pretest	CEEB Math	V Score	Blyth Algebra Post test
101	28	320	-0.13	23
102	16	410	0.29	20
103	11	400	x	27
104	19	x	x	33
105	15	x	x	24
106	11	410	x	20
107	16	310	-0.11	21
108	16	430	-0.16	17
109	17	x	x	27
110	10	420	0.10	14
111	22	x	x	28
112	20	470	-0.27	23
113	27	510	0.04	27
114	20	630	x	29
115	3	680	x	18
116	15	x	x	21
117	14	440	-0.03	27
118	17	420	x	37
119	27	500	-0.13	34
120	18	x	x	26
121	17	410	x	22
122	23	390	-0.00	33
123	17	430	x	27
124	23	520	0.40	37
125	12	490	x	20
126	16	500	0.23	26
127	24	440	x	37
128	21	380	-0.17	20
129	8	300	-0.04	19

TABLE 5

ANALYSIS OF COVARIANCE SUMMARY
BLYTH ALGEBRA PRETEST AND POST TEST

	α			β		
	No. Cases	Mean	S.D.	No. Cases	Mean	S.D.
Blyth Algebra Pretest	31	19.39	6.30	29	17.34	5.81
Blyth Algebra Post test	31	32.22	6.32	29	25.41	6.27

Analysis of Covariance

Source of variation	df	ssy.x	msy.x
Among means	1	450.65	450.65
Within groups	57	1502.49	26.36

SDy.x = 5.13 Fy.x = 17.10 $F_{0.01} = 7.11$

Adjusted post test means due to analysis of covariance and regression equation:

Mean post test α group 31.62

Mean post test β group 26.06

The difference 5.56 is significant by the F and T test at the .01 level.

TABLE 6

ANALYSIS OF COVARIANCE SUMMARY
V SCORE AND BLYTH ALGEBRA POST TEST

	α			β		
	No. Cases	Mean	S.D.	No. Cases	Mean	S.D.
V Score	18	0.37	.40	14	.01	0.19
Blyth Algebra Post test	18	31.5	6.53	14	24.36	6.72

Analysis of Covariance

Source of Variation	df	ssy.x	msy.x
Among means	1	127.31	127.31
Within means	29	1159.38	39.98

SDy.x = 6.32 Fy.x = 3.18 $F_{.01} = 7.60$

Adjusted post test means due to analysis of covariance and regression equation:

Mean post test α : 30.39

Mean post test β : 25.74

The difference 4.65 is not significant by F or T test at the .01 level.

TABLE 7

ANALYSIS OF COVARIANCE SUMMERY
CEEB MATH AND BLYTH ALGEBRA POST TEST

	α			β		
	No.Cases	Mean	S.D.	No.Cases	Mean	S.D.
CEEB Math	24	481.67	82.87	23	443.91	88.93
Blyth Algebra Post test	24	32.5	6.57	23	25.31	6.78

Analysis of Covariance

Source of Variation	df	ssy.x	msy.x
Among means	1	528.16	528.16
Within means	44	1946.16	44.23

SDy.x = 6.64 Fy.x = 11.94 $F_{.01} = 7.25$

Adjusted post test means due to analysis of covariance and regression equation:

Mean post test α : 32.26

Mean post test β : 25.38

The difference 6.88 is significant by F and T test at the .01 level.

TABLE 8

F TEST FOR RATIO OF POST TEST VARIANCES

$$F = \frac{n_\alpha s_\alpha^2}{(n_\alpha - 1)\sigma_\alpha^2} \div \frac{n_\beta s_\beta^2}{(n_\beta - 1)\sigma_\beta^2}$$

$H_o : \sigma_\alpha = \sigma_\beta$

$H_1 : \sigma_\alpha \neq \sigma_\beta$ $F_{.01} = 2.47$

Since $s_\alpha = 6.32$, $n_\alpha = 31$

and $s_\beta = 6.27$ $n_\beta = 27$,

then F = 1.01 and H_o was accepted

TABLE 9

STATISTICAL ANALYSIS OF TIME DEVOTED TO COURSE

	No. of Cases	Sample Standard Deviation	Sample Mean
Experiment Group α	31	11.12	31.44 hours
Control Group β	29	10.16	27.46 hours

$$t = \frac{\bar{x}_\alpha - \bar{x}_\beta}{\sqrt{\frac{(s_\alpha)^2}{n_\alpha} + \frac{(s_\beta)^2}{n_\beta}}} = 1.45 \qquad t_{.01} = 2.71$$

There is no significant difference in the means.

correlation of 0.632 between unit test average scores and post test scores for group β. This researcher was pleased with the correlations considering the fact that one set of tests was prepared by the authors of the audio-tutorial text and the other set of tests was prepared by the project director and both sets of tests were constructed using only face validity.

The unit test average scores for each group were computed. A review of Table 10 indicates that the group mean of the experimental group α exceeded the control group β on 11 of the 14 units. This result is compatible with other results obtained in this study.

The attitude survey had as its basic function the monitoring of the work of the student assistants. A copy of the attitude survey is included in Appendix E. Appendix E also provides detailed results of the survey. Thirty completed forms were received from group α and 27 from group β. Although only raw data is given in the appendix the results were analyzed using a chi-square test. The results indicated that the student assistants' work was viewed as favorable but not outstanding, a performance that can be duplicated with senior mathematics majors on a regular basis. It is doubtful that the student assistants contributed significantly to the performance of the control group β. This is as it should be. The eight items relating to student assistants were answered only by group β participants. Forty-eight of the 57 students responding felt that the learning system was well organized and 46 thought it had many advantages over the lecture discussion technique used in other mathematics courses. The difficulty level of the material seemed appropriate and the attitude toward learning using the learning system in this experiment was very positive. The response to item 9 by group α was significantly different from the response by group β. Twenty-three of the 30 students responding in group α thought some of the mathematics topics should have been explained more thoroughly whereas only 9 of the 27 students responding in group β responded in a similar fashion. The problem sessions provide an explanation for the difference in the responses. Item 7 provided a check on item 9. Although the results are not as significant, 14 of the 30 students responding from group α felt they did not receive an adequate explanation of each mathematics topic whereas only 7 of the 27 students responding in group β responded in a similar manner.

TABLE 10

UNIT TEST AVERAGE SCORES BY GROUP

Unit	Experimental Group α	Control Group β
1	17.46	17.30
2	17.75	17.56
3	17.68	17.03
4	16.87	16.13
5	17.43	17.00
6	16.21	16.68
7	16.93	16.62
8	17.59	17.18
9	17.06	16.38
10	17.31	17.66
11	18.62	17.91
12	18.45	17.58
13	17.46	17.54
14	16.64	16.63

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Two manageable and efficient audio-tutorial learning systems based on the audio-tutorial materials developed under Project 70 at Fullerton Junior College, Fullerton, California were developed in such a way that college students at Hendrix College learned mathematics skills associated with intermediate algebra at a level significantly above the national average as measured by the Blyth algebra test norms. The two learning systems were compared. Students receiving no help from student assistants but studying mathematics in a linearly ordered learning system under the direction of student assistants had mean scores significantly higher than the mean score of students receiving help from student assistants and studying mathematics in a linearly ordered learning system. Both group means were above the national average based on post test norms. The systems were organized by a member of the Hendrix College mathematics staff, otherwise no member of the staff was involved. The cost of teaching intermediate algebra was reduced from $60.00 to $32.00 per student. In addition to a reduction in cost per student, the mathematics teaching staff was free to devote more time to upper level courses. The program resulted in two desirable benefits for a small private liberal arts college; a saving in instructional cost and the development of a broader curriculum for mathematics majors.

This researcher feels that students capable of directing their own learning of low level mathematics skills need reinforcement and guidelines for performance. Adequate research results are available from other sources to support this claim. However, a dependency relationship between students and instructor can cause a student to procrastinate and faulter in his work. The myth that one can master great numbers of skills in algebra during the last few days of a course was definitely a factor in this experiment. Interviews with students in group β clearly show that most students felt that since help was available one could wait until the last few days of the term to finish the course. Most of the students did finish the course but with only superficial involvement. Learning was not accumulative and performance on the post test was poor. On the other hand, the attitude survey indicates there is a need for clarification of mathematical concepts not adequately covered in any set of instructional materials. Perhaps such assistance can be provided by student assistants and without the development of a dependency relationship between instructor and student. Additional research is needed to investigate this matter.

Recommendations

Small liberal arts colleges should give serious consideration to the development of audio-tutorial learning systems to be used in the teaching of low level mathematics concepts. Concepts taught in conventional college algebra, modern mathematics for elementary teachers, and general education mathematics can be taught efficiently. Each college should develop its own learning system but use commercially produced materials whenever possible. Audio-tutorial materials are available and the state of technology related to Cassette players and filmstrip viewers is satisfactory.

Student assistants should be junior or senior mathematics majors interested in teaching mathematics either at the high school or college level. The student assistants should direct the learning system with only limited involvement by the mathematics instructional staff. Student assistants should generally limit their role to administering and grading tests and the maintenance of records for evaluation purposes. However, clarification of concepts not adequately treated in the learning system should be permitted.

It is further recommended that studies be made as to the feasibility of incorporating audio-tutorial 35 millimeter slides and drill cards into an audio-tutorial learning system. Slides and drill cards might provide a way of giving a personal touch to the instructional materials by the mathematics staff in a specific college. This researcher is presently preparing a proposal which if funded would allow for the incorporation of 35 millimeter slides and drill cards into the learning system developed in this project. The intent is to add depth to the system to meet specific local needs.

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APPENDIX A

Discriminatory Analysis Guide
for Freshman Placement in Mathematics
at Hendrix College

Dr. Cecil W. McDermott

Hendrix College

Conway, Arkansas

June 3, 1971

This project was conducted through a grant from the Arkansas Educational Research Stimulation Program of the U.S. Office of Education and administered by the Arkansas Commission on Coordination of Higher Educational Finance.

DISCRIMINATORY ANALYSIS GUIDE
FOR FRESHMEN PLACEMENT IN MATHEMATICS
AT HENDRIX COLLEGE

I. Statement of the Problem and Objectives

Entering freshmen students at Hendrix College in the fall of 1971 will be placed in one of our courses: precalculus mathematics, calculus, contemporary mathematics, or Math Lab. The students are placed according to their past performances in high school mathematics courses, total grade point average, and college entrance examination scores. The placement procedure has emphasized an "intuitive feeling" about the student's potential mathematical ability rather than fully utilizing the data available. The purpose of this project is to make it possible to utilize four years of data in running a discriminatory analysis to properly place freshmen students in freshmen level courses in such a way as to maximize their chances for success in the course for which they are best qualified.

II. Method of Research

This researcher has maintained a detailed set of data on all entering freshmen since the fall of 1967. Each student's grades in high school mathematics courses, overall grade point average, College Entrance Board (CEEB) verbal and mathematics scores, and two standardized mathematics test scores have been available for statistical analysis. Also available were the grades each student made in his freshman mathematics courses: calculus, college algebra, and trigonometry.

The statistical technique of discriminatory analysis was used to find the variables which best predicted a student's chances of success in each of the freshman mathematics courses. Success was defined as a predicted grade of C or better and failure was defined as a predicted grade of D or F.

The discriminatory analysis was carried out using Olivetti Underwood P101 and IBM 360-50 64K computers. The results consist of an equation involving five variables. The number generated by the equation is a prediction about a student's chances of success in either calculus or precalculus mathematics.

III. Resume of Findings

(a) Data characteristics

Data was obtained on 1170 freshmen students who have entered

Hendrix College since 1967. Of these students, 313 were successful in freshman mathematics (A, B, or C in calculus, or A, B in college algebra) and 193 were not successful (D, F in calculus and C, D, F in college algebra). Complete data on six variables have been obtained. The variables are: (1) freshmen mathematics grades, (2) CEEB verbal scores, (3) CEEB mathematics scores, (4) overall high school grade point average, (5) a rating of mathematical grades and courses, and (6) a high school incentive quotient defined especially for this project.

(b) The Discriminate Equation

The biserial correlation coefficient is satisfactory for determining the relationship between a dichotomized variable and one continuous variable. However, it is often desirable to predict a dichotomy from several numerical variables. Just as multiple regression yields appropriate weight for utilizing more than one variable in predicting a numerical criterion, so also an equation can be used in predicting a variable dichotomy. The latter equation is called a discriminant equation. A coefficient of multiple biserial R can be obtained from a discriminant equation and is similar to the coefficient of multiple correlation.

A discriminant equation, originally developed by R. Z. Fisher, is very useful in ascertaining appropriate weights for a series of variables yielding maximum separation of two groups, each of which is assumed to be normally distributed. The equation may be expressed as $V = a_1x_1 + a_2x_2 + ... + a_mx_m$ where $x_1, x_2, ...x_m$ are continuous variables and $a_1, a_2, ...a_m$ are coefficients. The coefficients for the equation are found by solving a series of simultaneous equations similar to the normal equations used in multiple regression analysis.

The discriminant equation lends itself to the prediction of success in a specific course and upon solution the output of the equation is in deviation form with a range of about -3 to +3. The equation can be changed from deviation form.

The equation obtained in this study is in raw score form. An equation for placing students in freshman calculus mathematics was obtained using data on four freshman classes. The equation is $V = 0.0008956x_1 + 0.001098x_2 + 0.1898x_3 + 0.02525x_4 + 0.01027x_5 - 2.3953$. A student is placed using this equation only if he has successfully completed trigonometry.

When applied to all students involved in the study the placement procedure was 84% accurate.

V scores for students were obtained and cut off points were established so that the best accuracy could be obtained on 496 students whose grades in freshman mathematics we had obtained. Cut off V scores were selected so that the predictions coincided with the results as much as possible. A student with a V score of 1.29 or more will be strongly recommended for calculus. A student with a score from 0.68 to 1.28 will be recommended for calculus. A student with a score from 0.51

to 0.67 will be recommended for calculus with caution.

An equation for placing students in freshman precalculus mathematics was obtained to be used in placing students without trigonometry. It yields a set of V scores that would be obtained from the calculus equation. The following equation is just as accurate for placement purposes as the calculus equation: $V = 0.0008956x_1 + 0.001098x_2 + 0.1898x_3 + 0.02525x_4 + 0.01027x_5 - 1.9153$. A student with a V score of 0.50 or higher will be recommended for elementary functions. A student with a V score of 0.25 to 0.49 will be recommended for elementary functions with caution. A student with a V score of 0.24 or lower will be recommended for Math Lab or contemporary mathematics.

It should be noted that the placement procedure outlined in this report results in a recommendation to the student and the student's advisor. A student will be encouraged to follow the recommendation, however one may feel his background is stronger or weaker than that indicated by the V score. Therefore, a student may actually enroll in Math Lab when it was recommended that the student take elementary functions.

APPENDIX B

INTERMEDIATE ALGEBRA

Topics Included in Learning Systems

Unit 1: Introduction to Sets

Unit 2: Graphs of the Number Line

Unit 3: Review of Field Properties - Part I

Unit 4: Review of Field Properties - Part II

Unit 5: Factoring

Unit 6: Fractions

Unit 7: Exponents

Unit 8: Radicals

Unit 9: Solution Sets of Linear Equations

Unit 10: Solution Sets of Quadratic Equations

Unit 11: Relations and Functions

Unit 12: The Linear Functions

Unit 13: The Quadratic Function

Unit 14: The Binomial Theorem

APPENDIX C

TIME DEVOTED TO COURSE

Experimental Group α		Control Group β	
Student Code	Number of Hours Devoted to Course	Student Code	Number of Hours Devoted to Course
1	24.75	101	18.75
2	27.75	102	20.25
3	22.75	103	53.00
4	25.75	104	25.75
5	34.50	105	30.25
6	38.25	106	31.75
7	43.50	107	38.75
8	28.75	108	23.75
9	22.75	109	18.50
10	19.25	110	15.25
11	29.75	111	26.50
12	20.00	112	25.25
13	26.75	113	16.50
14	30.00	114	22.75
15	15.50	115	22.50
16	39.50	116	39.00
17	33.00	117	27.50
18	36.75	118	29.00
19	14.00	119	12.75
20	44.25	120	23.25
21	19.25	121	44.75
22	18.25	122	25.75
23	49.75	123	15.25
24	40.25	124	21.00
25	37.75	125	21.25
26	29.75	126	44.00
27	32.25	127	41.00
28	28.75	128	22.50
29	34.00	129	40.00
30	40.25		
31	67.00		

APPENDIX D

FINAL GRADE ASSIGNMENT

Experimental Group α		Control Group β	
Student Code	Grade	Student Code	Grade
1	P	101	P
2	P	102	P
3	P	103	P
4	P	104	P
5	P	105	P
6	P	106	*F
7	P	107	P
8	P	108	*F
9	*F	109	P
10	P	110	*F
11	P	111	P
12	P	112	P
13	P	113	P
14	P	114	P
15	P	115	*F
16	P	116	P
17	P	117	P
18	P	118	P
19	P	119	P
20	P	120	P
21	P	121	P
22	P	122	P
23	P	123	P
24	P	124	P
25	P	125	P
26	P	126	P
27	P	127	P
28	P	128	P
29	P	129	P
30	P		
31	P		

*All five students with grade of F failed to meet either of the two required criterias for passing; a score of 26 in the post test or complete 12 units with 70% score.

APPENDIX E

PEARSON r CORRELATION COEFFICIENT

Unit Test Average and Post test

Experimental Group α

Student Code	Unit Test Average	Post Test
1	17.57	33
2	16.35	25
3	14.35	22
4	15.92	24
5	16.64	40
6	18.14	35
7	17.20	34
8	17.28	29
9	*17.09	25
10	18.64	30
11	17.07	32
12	18.00	37
13	16.57	24
14	18.21	35
15	17.92	41
16	17.00	30
17	17.35	38
18	17.64	39
19	18.57	36
20	14.07	22
21	16.07	36
22	18.92	45
23	16.85	30
24	17.15	28
25	15.92	36
26	16.91	40
27	15.85	24
28	17.35	33
29	15.35	31
30	17.50	40
31	16.69	25

Pearson r = 0.611

Control Group β

Student Code	Unit Test Average	Post Test
101	16.42	23
102	15.64	20
103	16.50	27
104	17.85	33
105	16.21	24
106	15.40	*20
107	17.00	21
108	13.42	*17
109	16.92	27
110	16.16	*14
111	18.00	28
112	17.85	23
113	17.00	27
114	18.14	29
115	15.00	*18
116	16.85	21
117	17.07	27
118	17.70	37
119	17.57	34
120	17.07	26
121	15.92	22
122	18.07	33
123	17.07	27
124	17.28	37
125	17.00	20
126	17.57	26
127	17.92	37
128	18.60	20
129	13.92	19

Pearson r = 0.632

*Based on fewer than 12 unit scores but more than 8.

APPENDIX F

Experimental Group____________ Date____________

ATTITUDE SURVEY

The items in this attitude survey are statements to which you are asked to indicate your immediate reaction. Check the appropriate square indicating your feeling. Please read the statements as quickly as possible and answer without much hesitation. Do not skip any questions unless it is clearly marked to be omitted by your group.

1. The audio-tutorial text covered some topics which were new to me.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

2. Some of the materials in the audio-tutorial text were too difficult.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

3. I got bored working through the audio-tutorial text.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

4. Some of the materials in the audio-tutorial text were too easy.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

5. I thought the learning system was well organized.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

6. I can't see much advantage of this system over the traditional lecture-discussion method of instruction.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

7. I received an adequate explanation of each mathematics topic.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

8. Some of the material in the learning system was repetitious.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

9. Some of the mathematics topics should have been explained more thoroughly.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

10. Intermediate algebra is very interesting.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

11. I enjoy doing my work alone.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

12. I like variety in the ways of learning mathematics.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

13. The student assistants were qualified to manage the learning system.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

14. The student assistants presented the concepts at a level appropriate for students without previous knowledge of intermediate algebra.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

15. The student assistants made little effort to prepare for the problem sessions.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

16. The student assistants were unable to hold my attention and interest in the problem sessions.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

17. The problem sessions added value to the course.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

18. I got bored during the problem sessions.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

19. I learned new ways of thinking about problems from discussions in problem sessions.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
○	○	○	○	○

20. The problem sessions were not very helpful.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
◯	◯	◯	◯	◯

21. I wouldn't have understood the basic concepts of intermediate algebra without the problem sessions.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
◯	◯	◯	◯	◯

22. There are many advantages of this system as opposed to the lecture discussion technique used in other math courses.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
◯	◯	◯	◯	◯

APPENDIX F (Continued)

ATTITUDE SURVEY RESULTS

Item		Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	α	9	16	0	4	1
	β	10	11	0	4	2
2	α	1	4	4	11	10
	β	2	4	1	17	3
3	α	1	7	7	12	3
	β	1	5	1	18	2
4	α	1	4	10	[illegible]	1
	β	0	1	13	7	6
5	α	16	9	3	2	0
	β	15	8	2	2	0
6	α	1	1	2	17	9
	β	2	0	2	12	11
7	α	5	11	8	5	1
	β	4	16	3	3	1
8	α	1	11	2	16	0
	β	1	5	1	18	2
9	α	3	16	4	7	0
	β	0	3	6	14	4
10	α	3	13	8	2	4
	β	6	8	6	7	0
11	α	6	14	5	3	2
	β	3	17	3	3	1

APPENDIX F (Continued)

ATTITUDE SURVEY RESULTS

Item		Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
12	α	7	15	6	0	2
	β	7	17	1	2	0
13	α	8	9	13	0	0
	β	9	13	5	0	0
14	α	x	x	x	x	x
	β	2	15	7	3	0
15	α	x	x	x	x	x
	β	0	1	13	7	6
16	α	x	x	x	x	x
	β	0	1	13	7	6
17	α	x	x	x	x	x
	β	10	7	8	1	1
18	α	x	x	x	x	x
	β	0	0	9	14	4
19	α	x	x	x	x	x
	β	2	9	10	5	1
20	α	x	x	x	x	x
	β	0	3	6	14	4
21	α	x	x	x	x	x
	β	2	4	13	6	2
22	α	7	15	6	2	0
	β	7	17	2	1	0